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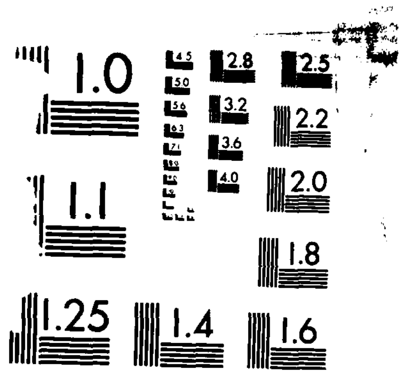
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The overall objective of this program was to characterize the environments and conditions under which dust storms are generated in North Africa. To this end, the activities in this program focused on three specific research topics:

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1. A study of the wind velocity necessary to initiate deflation at various sites in the Sahara:

Of the 41 dust events that occurred at 8 meteorological stations in the summer of 1974, 32 (78%) were associated with winds between 6.5 - 13.5 m s^{-1}. The mean wind speed for all dust raising events was 10.5 m s^{-1}; while that for reports where no deflation was observed was 4.5 m s^{-1}. The average of the highest wind speeds observed in the absence of deflation at each station is 9 m s^{-1}, a value that is quite close to the mean for the lowest wind speeds observed during deflation events. The data at each of the stations appear to be internally consistent and, consequently, they appear to reflect environmental characteristics of the locality. The mean threshold value for the eight stations does not differ greatly from values previously mentioned in the literature for arid regions in other parts of the world. These results are useful as a general predictor for threshold velocities in this region.

2. An investigation of the meteorological factors that are asociated with major dust storm genesis in West Africa in the summer of 1974:

A total of 17 major dust occurrences were identified during the period June to September; most occurred in a relatively localized region west of the Ahaggar mountains. Major dust storms were associated with characteristic large scale synoptic features, including the isallobaric pattern ~~and the~~ flow patterns in the 850-700 mb layer and at the surface. Considerations are 1) the existence of a well developed surface cyclone along the ITF south of the dust source region; 2) the pressure gradient between a point 10^{o} to the north of the cyclone and the cyclone center; 3) the longitudinal location of the cyclone center relative to the dust source region. Most major storms occurred when there was a cyclone in the vicinity of 0^{o} longitude and when there were pressure differences of 4 mb or greater over 10^{o} of latitude. Such gradients generated geostrophic winds of at least 8.5 m/sec over the source region. Our studies suggest that these two factors can be used to predict the occurrence of the dust clouds with a high degree of accuracy.

3. A systematic study of the location of all West African dust storms visible on SMS-1 satellite imagery in the summer of 1974:

Images for 27 important dust storm days were digitally enhanced on the McIDAS interactive analysis system at the University of Wisconsin. The prime deflation sites for major dust storms were the great sebka complexes of the region west of the Ahaggar massif -- Sebka Meqerghane, El Haricha, the Azlef-Mdenna-Keila and eastern Karet. Dust plumes did not develop in the Ahaggar, nor did they develop on the West Sahara Shield, toward Tindouf and Emmour. All of the Tanezrouft provided dust at one time or another during this summer. Plumes can be grouped into three distinct styles. The commonest pattern and the most dramatic in size is the NE-to-SW plume. The orientation is primarily determined by the synoptic wind field. These plumes often start near the Sebka Meqerghane and trend toward the Haricha region.

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ENVIRONMENTAL CONDITIONS ASSOCIATED WITH THE OCCURRENCE OF LARGE SCALE DUST STORMS IN ARID REGIONS OF NORTH AFRICA

FINAL REPORT

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Statement of Problem Studied

Dust storms are a frequent occurrence in many arid regions of the world. The areal extent of these dust outbreaks is measured in tens to hundreds of thousands of square kilometers and dust concentrations in such events are often sufficient to severely restrict visibility. Frequently the vertical development of dust storms is so great that the earth's surface is obscured (or even invisible) from altitudes greater than a kilometer or so.

The study of the environmental conditions associated with such dust events has been hampered by the fact that the storms frequently occur in areas which are uninhabited or, at best, only sparsely inhabited. Also, the distribution of meteorological stations is often inadequate in these regions. Thus, it is difficult to develop an observational data base which enables us to both identify the specific geographical locations where dust storms are endemic and to characterize the meteorological phenomena associated with such storms.

The overall objective of this program was to characterize the environments and conditions under which dust storms are generated in North Africa. This objective was accomplished in the following manner:

1. We used satellite imagery to identify areas where dust storm activity is especially great;

2. We used topographical, geological and soil maps and reviews of published literature to characterize the environment in the dust source regions;

3. We used synoptic meteorological data to identify the conditions necessary to initiate dust episodes and, on this basis, to develop a predictive capability.

Summary of Important Results:

The activities in this program focused on three specific research topics:

1) A study of the wind velocity necessary to initiate deflation at various sites in the Sahara;

2) An investigation of the meteorological factors that are associated with major dust storm genesis in West Africa in the summer of 1974;

3) A systematic study of the location of all dust storms visible in satellite imagery in West Africa in the summer of 1974.

These results are discussed separately.

1. Threshold wind velocity for dust deflation:

The results described in this section are extracted from a paper (Threshold Wind Velocities for Raising dust in the Western Sahara, by J.

Fernandez-Partagas, D.M. Helgren and J.M. Prospero) which has been submitted for publication in the Journal of Climate and Applied Meteorology. A somewhat longer version is available as a technical report of the same title, copies of which have been sent to the agency under separate cover.

The threshold velocity is the minimum wind speed required to initiate deflation of surface sediments. Consequently it is one of the most important parameters governing the wind erosion and subsequent transport of soil dust. At the threshold velocity the aerodynamic drag on the surface is sufficient to dislodge particles from the surface, setting them in motion and lifting them into the atmospheric boundary layer. The threshold velocity depends on a number of soil and sediment characteristics such as particle sizes and shapes, soil composition and moisture content, and the aerodynamic properties of the surface. Because soil properties can be quite variable, the threshold wind velocity could vary widely from place to place and even with time at the same place.

Threshold wind velocities have been reported for a number of environments in the United States and the U.S.S.R. However, to our knowledge, in the Sahara the threshold velocity has been determined for only one station in Sudan.

For this study we chose the period 1 July - 15 August, 1974 which coincided with the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE). GATE provided us with a larger meteorological data set and improved coverage of North Africa via the SMS-1 geostationary satellite.

For our study we used data from the major reporting stations in the western Sahara: Beni Abbes, Timimoun, Ain Salah, In Amenas, Ghadames, Fderick, Nouadhibou and Akjoujt (Fig. 1). All are located in hyperarid regions. Data on surface wind speed and dust-related phenomena were obtained from the 1200 GMT surface meteorological observations from the eight stations. We used only the 1200 GMT data because the analysis of IR satellite imagery showed that major dust storms generally began in the late morning and the early afternoon. The standard meteorological reporting codes permit the identification of four different types of dust-related conditions: 1) dust being raised from the ground at the time of observation; 2) dust storms; 3) dust suspended in the air but not being raised from the ground at the time of observation (presumably remnants of an earlier deflation event); and 4) haze (presumably caused by dust). In our study, the surface wind speed and the dust phenomena (when reported) were tabulated and then plotted in the form of frequency diagrams for each station. The tabulations and diagrams allow us to determine the lowest wind speed capable of raising dust from the ground (the threshold wind velocity) at each station. They also allow us to determine the highest wind speed that occurred in the absence of rising dust, a value that can be used to confirm the threshold wind velocity.

Of the 41 events, 32 (78%) were associated with winds between 6.5 - 13.5 m s^{-1} (Table 1). The mean wind speed for all dust raising events was 10.5 m s^{-1}; however, the means for the individual stations extended over a considerable range, from 6.5 m s^{-1} to 13 m s^{-1}.

Also recorded was the lowest wind speed observed in association with a dust rising event at each station. These values can be regarded as the characteristic threshold velocity for each station. The mean of the lowest deflation wind speed at each station was 8 m s^{-1}; again, the range is rather broad, 5 to 12.5 m s^{-1}. The mean wind speed for all meteorological observations where no deflation was observed was 4.5 m s^{-1}. Included in this category are: 1) reports of haze; 2) cases of dust suspended in the air but not being raised from the ground at the time of the observation; and 3) meteorological reports that do not cite any dust-related phenomena. The highest wind speed observed in the absence of deflation at each station is also shown in Table 1; the average of these maximum dustless winds is 9 m s^{-1}, and the range is 6 to 11 m s^{-1}, values that are quite close to those observed for the lowest wind speeds observed during deflation events.

We summarize in Fig. 2 the frequency of occurrence of dust events (expressed as a percentage of the total number of meteorological reports) at all stations as a function of wind speed. Note in the figure that there is a significant increase of dust-raising cases from the 5 to the 7.5 m s^{-1} categories; the increase reflects the fact that the average threshold wind velocity for the eight stations 8 m s^{-1} is in the 7.5 m s^{-1} wind category. Deflation is observed at all times at wind speeds in the range of 11.5 to 13.5 m s^{-1} and above. Also displayed in Fig. 2 are the percentages of haze cases and of cases of dust suspended in the air (but not being raised from the ground). In contrast with the dust-raising cases, the percentages of haze cases and of cases of dust suspended in the air (but not being raised from the ground) start to decrease at the 7.5 m s^{-1} wind category.

The data at each of the stations appear to be internally consistent and, consequently, they appear to reflect environmental characteristics of the locality. Variations are most likely attributable to different terrain conditions at the stations and probably in some cases to land use practices. Although the range of threshold values was relatively large, the mean threshold value for the eight stations does not differ greatly from values previously mentioned in the literature for arid regions in other parts of the world.

These results are useful as a general predictor for threshold velocities in this region. However, meteorological records at individual stations would serve as a more reliable predictor for more localized areas.

2. Meteorological factors associated with dust storm genesis:

The results described in this section are extracted from a technical report entitled "Genesis of Major Dust Storms in West Africa During the Summer of 1974", by M. Estoque, J. Fernandez-Partagas, D.M. Helgren and J.M Prospero. Copies of this report have been sent to the agency under separate cover. A shortened version of this report is being prepared for submission to an appropriate journal.

The generation of large scale dust episodes over arid and semiarid landscapes requires two atmospheric conditions: 1) surface winds sufficiently strong to cause erosion (as described in the preceeding

section) and, 2) strong vertical transport to carry the dust into the troposphere. Vertical transport of dust can occur under conditions of unstable thermal stratification because of the development of intense turbulent eddies ranging in size from small scale to convective scale. These eddies can transport dust from the surface layer upward into the middle and upper troposphere. In addition, the upward transport of dust also can result from large-scale synoptic upward motions. For example, dust storms in China are generated as a rapidly moving cold fronts overtake slower fronts.

While it is clear that the genesis and subsequent transport of dust clouds in the atmosphere is dependent on many meteorological variables, there have been no detailed and systematic studies of the synoptic conditions associated with major dust events. Most reports in the literature consist of isolated case studies or of a generalized discussion of the meteorology of such events.

The principal objective of this study is to investigate the meteorologial settings of major dust storms occurring in the western Sahara (Fig. 3).

During the summer, over West Africa, there are two types of synoptic disturbances that are characterized by strong surface winds and unstable thermal stratification. One of these types is an intensifying anticyclone over northwest Africa. The southeastern periphery of this anticyclone is usually characterized by strong winds and unstable conditions. This type of flow pattern is most common in winter and spring, but it also occurs in the summer, although usually with less intensity. The other type of dust-related synoptic flow pattern in the summer is characterized by a cyclonic disturbance. This disturbance develops at the surface along the Intertropical Front (ITF) and generally propagates westward. The surface cyclone is generally reflected at upper levels as a wave trough, which may be responsible for the typical flow pattern observed at 700 mb during Saharan dust outbreaks as they pass off the coast of West Africa. Presumably, there are other types of synoptic situations which might also trigger large scale dust episodes. However, the sparsity of meteorological observations in the Sahara, especially upper air observations, has made it difficult to study meteorological events in detail.

This study focuses on the summer of 1974, which coincided with the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE). GATE provided us with a large meteorological data set and improved coverage of North Africa via the SMS-1 geostationary satellite.

Specific objectives are:

(1) To provide a detailed description of the synoptic conditions for this period;

(2) To identify the synoptic flow patterns that are associated with the occurrence of large scale dust clouds during this period; and

(3) To develop empirical models of the synoptic flow patterns that generate large scale dust clouds.

A variety of synoptic map products were prepared for the entire GATE period. Streamline analysis techniques were used and isallobaric maps were prepared. Dust storms were located on these map products by means of SMS1 infra red imagery.

A total of 17 major dust occurrences were identified during the period June to September; 9 of these occurred during July. Most major dust storms occurred in a relatively localized region west of the Ahaggar mountains (Fig. 4). By means of compositing methods, we found that all the major dust episodes occurred when a surface cyclone was present along the ITF, south of the dominant dust source region. This cyclone had to be sufficiently strong to generate geostrophic winds of at least about 17 knots (8.5 m/sec) over the source region.

Two types of flow patterns were observed in the 850-700 mb layer during dust episodes. One type is characterized by an anticyclonic flow pattern while the other is characterized by a cyclonic pattern with a 700 mb wave trough in the vicinity of the dust plume. None of these two types appear to agree with the model of the 700 mb flow pattern previously described for the eastern Atlantic.

The two types of flow pattern at the 850 - 700 mb layer are associated with two different types of isallobaric patterns at the surface. The anticyclonic flow pattern aloft is associated with pressure rises over Northwestern Africa, implying an intensification of a surface anticyclone over the area and a strengthening of the wind over the dust source region. On the other hand, the type with the cyclonic flow pattern aloft is associated with large pressure falls in the vicinity of the ITCZ, south of the dust source region, as well as pressure rises to the north. The falls imply an intensification of a cyclone in the region of large pressure falls. In this case, the increase in the wind speed in the source region is due to the intensification of both the surface cyclone and the anticyclone to the north. There are indications that the intensification of the anticyclone to the north or northeast of the surface cyclone is related to decreases in surface temperatures in the same area.

In summary, the occurrence of major dust clouds over the western Sahara is associated with several characteristic features of the large scale synoptic conditions, including the isallobaric pattern as well as the flow patterns at the 850-700 mb layer and the surface. A necessary ingredient for the occurrence of dust appears to be the existence of a well developed and intense surface cyclone along the ITF south of the dust source region. These three features are incorporated in three synoptic models for dust generation. The models are: the general model (GM), the model without a trough (NTM) and the model with a trough (TM). Conditions resembling those in the TM appear to be the ones most frequently observed during dust episodes in GATE.

Two other factors are related to the occurrence of large-scale dust storms: the pressure gradient between two selected points (a point 10

degrees to the north of the cyclone and the cylone center itself) and the longitudinal location of the cyclone center relative to the dust source region. Our studies suggest that these two factors can be used to predict the occurrence of the dust clouds with a high degree of accuracy.

To assess the importance of the horizontal pressure gradient as a factor in the generation of dust clouds, we examined first the time series of the daily values of the surface pressure at two points: 30^{0}N latitude, 0^{0} longitude and 20^{0}N latitude, 0^{0} longitude. These locations were selected because the pressure gradient between them represents the east-west wind speed component across the major dust source region. The time series incorporates data for the period July 1, 1974 to August 15, 1974. The surface pressures at these two locations are shown in Fig. 5. Also shown in the diagram is the pressure difference (northern pressure minus southern pressure) and the corresponding east-west component of the geostrophic wind speed. The days on which dust clouds were observed are indicated by dashed lines. There are three days (July 1, 11, 21) when the pressure difference between the two points exceeded 8 mb. The large pressure differences are associated by rises in pressure over the northern region and decreases in pressure over the southern region; this situation corresponds to the occurrence of an anticyclone in the north and a cyclone to the south. As expected, dust clouds were generated on these days or the days following these maxima in pressure differences. There were six other days on which dust clouds occurred with smaller pressure differences. Two of these days had a rather small pressure difference of 4 mb. These data suggest that a pressure difference of more than 4 mb will usually result in the generation of major dust events.

Figure 6 shows the relative location of the cyclone center at the time that a major dust storm occurred. The location is specified in terms of the longitudinal distance of the cyclone center from the longitude (0^{0}) of the major dust source region. Using the longitudinal distance and the pressure difference (pressure at 10 degrees to the north of the center minus pressure at the cyclone center) as abscissa and ordinate, respectively, we plotted points corresponding to cyclones for each day in the time series. Cyclones associated with the major dust occurences presented here are indicated by crosses (X); cyclones that were not associated with dust events are indicated by dots. Two features are evident in Fig. 6. First, most points associated with strong pressure gradients and cyclones in the vicinity of 0^{0} longitude correspond to days when a major dust storm occurred. Second, major dust storms did not occur on days with strong pressure gradients when the cyclone centers were far from 0^{0} longitude. The data points for dust storm events are relatively tightly clustered while those for non-dust storm days fall predominantly outside the cluster. Hence, the diagram can be used to predict major dust events if the location of the cyclone center and the pressure gradient to the north of the cyclone are known.

3. Systematic study of the location and terrain characteristics of all major dust storms in the summer of 1974 in West Africa:

The results of this study are covered in two documents that are currently in draft stage. One is a detailed study of two of the largest dust storms that were ever observed; these occurred on July 28 and 29,

1974 (Terrains of the Great West African Dust Storms of July 28 and 29, 1974; D.M. Helgren and J.M. Prospero). The second paper is a larger scale (but less detailed) study of all the dust events of the summer of 1974 (Locations of Imprtant West Saharan Dust Storms, June 28 to September 24, 1974; D.M. Helgren and J.M. Prospero). These draft copies are being prepared for submission to the appropriate journals.

Dust storms are mapped here from SMS-1 satellite imagery collected during the summer of 1974 as part of the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE). During GATE the SMS-1 satellite was placed in a temporary equatorial geosynchronous orbit over 45W. This placement provided a veiw of Africa as far east as 20E. SMS-1 provided visible-band (0.4 - 0.7 micron) imagery of the western Sahara with a resolution of 2 nautical miles and infrared-band (10.5 - 12.5 microns) imagery with a resolution of 4 nautical miles.

SMS-1 imagery from GATE is available as 35 mm negative photographic products from which enlarged prints can be prepared. Most GATE SMS-1 imagery is also available in digital format and the available archive has been transcribed to storage on video cassettes at the Space Science and Engineering Center at the University of Wisconsin in Madison. Initially in our investigation, all of the SMS-1 imagery from GATE was examined on photographic products. From these scenes important dust storm days were selected for detailed analysis in digital format on the McIDAS interactive analysis system at the University of Wisconsin. The McIDAS system allows a series of infrared- and visible-band senes to be interactively enhanced and printed. With McIDAS, images can be navigated with considerably more accuracy than was available in the original product.

Three types of dust events are evident in SMS-1 data. Of greatest interest were the large-scale storms occurring in the relatively cloud-free western Sahara north of the ITF. Storm of this type served as the focus of the study discussed in the preceeding section. The second type consisted of dust events associated with ITF cloud clusters, which in the summer pass through the Sahelian zone (10N to 20N). This dust is very obvious in visible-band imagery as it moves offshore, but explicit deflationary episodes within the ITC could not be picked out. In the third category are small-scale deflationary events in the central desert. These events are often less than 5000 km^2 in area and are usually centered over deflation foci such as ephemeral lake beds. Similar "small" storms are probably characteristic beneath developing Easterly Waves but these are difficult to verify from SMS-1 imagery because of nearby water clouds. Similarly, as Easterly Waves move westward over the coast, they often generate dust from as yet unidentified sources in the coastal region.

The important GATE dust plumes were placed in the context on a map of the landform regions of the western Sahara. This map has been developed from selected 1:2,000,000 geological charts of the C.N.R.S. (Paris) and the terrain renderings of the 1:1,000,000 Carte International Du Monde (Institute Geographique National, Paris). It must be emphasized that this part of the Sahara is one of the most arid regions of the world. The central parts of the mapped area probably have annual average rainfalls of less than 2 cm which means for several years it may not rain at all. The uplands of the Ahaggar receive enough rain, perhaps averaging 20 cm per

year, to be considered almost semiarid. Similarly, terrains south of about 22N can expect more than 10 cm of largely summer rains in an average year. Vegetation response is comparably limited. Apart from brief florescences after rains, many areas have few flowering plants, while in moister areas hardy grasses and low shrubs provide a discontinuous ground cover. In general, the soil/sediment surface is continuously open to wind erosion.

The prime deflation sites were the great sebka complexes of the region -- Sebka Meqerghane, El Haricha, the Azlef-Mdenna-Keila and eastern Karet. Dust plumes did not develop in the Ahaggar, nor did they develop on the West Saharan Shield, toward Tindouf and Emmour. All the gravel-covered Tanezrouft provided dust at one time or another during this summer.

Plumes can be grouped into three distinct styles. The commonest pattern is the NE to SW plume, often starting near the Sebka Meqerghane and trending towerd the Haricha region. Of the 27 GATE plumes, eleven were of the NE-SW style. The second type consists of the dusty fronts of "Northward Bound Parcels" (NBP) surging northward from the ITC circulations. Six plumes fall in this category. The third type consists of dust arcs, apparently tracing the northern edges of an ITC cyclone. Five GATE plumes followed this pattern. One plume combined the NE-SW and dust-arc styles, and four plumes defied simple categorization.

This mapping of the dust plumes during the GATE summer indicates that a west Saharan summer dust region can be defined. The axis of prime deflation extends from the Sebka Meqerghane region to the Haricha region with the eastern Tanezrouft and regions along the El Hank marging providing secondary deflation realms.

The most obvious research needs are field studies. Meso-scale wind dynamics around the western flanks of the Ahaggar seem to explain the prominence of the Sebka Meqerghane as a dust source. Similarly, deflation dynamics need to be compared against the surficial sediment suites of the different regions. Of interest is the relevance of the large-scale geology and geomorphology in understanding dust plume densities and location. Also required are studies of the deflation patterns and sources in the transition regions between different terrains.

Conclusions:

Dust storms are complex phenomena that are dependent on many meteorological and environmental factors. Because they normally occur in remote and in hospitable regions, they have been studied relatively little. Such studies are further hampered by the dearth of meteorological, climatological and geological data for such regions. To our knowledge, our study is the first to attempt to make an extensive study of these events in the Sahara which is without a doubt one of the largest dust sources on the Earth.

While our results are by no means definitve, they do suggest that there are a number of identifiable criteria that determine the time and place of occurrence of dust storms. In particular, the occurrence of the

major storms seems to be related to identifiable meteorological conditions; such storms should be predictable with a fair degree of confidence. Likewise, it is clear that there are a wide variety of terrains that can serve as dust sources given the right meteorological conditions. However, the truly great storms appear to occur in a relatively well defined region of the western Sahara, west and southwest of the Ahaggar masif. There are many terrains in this region that can serve as dust sources. As a consequence, the dimensions of the storm appear to be controlled by the wind field and, hence, serves as a visible manifestation of the governing synoptic event.

Our study also shows that there are many other smaller scale dust sources that are activated by smaller scale meteorological events. These could not be studied because of the absence of any meteorological data.

Also, there are major sources in the clouded regions associated with the ITF and the ITCZ. However, because of the cloud, these regions could not be studied. Nonetheless, sources in these areas are clearly very important and could control the aerosol characteristics over a large area of West Africa and the tropical and subtropical North Atlantic.

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Table 1

Wind Speeds Associated With Cases Where Dust Was Raised and Where Dust Was Not Raised

	Cases Where Dust Was Raised			Cases Where Dust Was Not Raised		
	# of Cases	Mean Wind Speed (Kt)	Lowest Wind Speed (Kt)	# of Cases	Mean Wind Speed (Kt)	Highest Wind Speed (Kt)
Ain Salah	6	13	10	35	9	14
Akjoujt	5	16	14	38	8	14
Beni Abbes	3	22	12	35	6	12
Fderik	2	19	18	39	8	20
Ghadames	2	26	25	42	9	20
In Amenas	5	16	14	30	7	17
Nouadhibou	9	25	20	34	15	22
Timimoun	9	26	17	25	14	21

Figure Captions

Fig. 1: Location of case study meteorological stations in Northwest Africa. Stippled areas are important highlands.

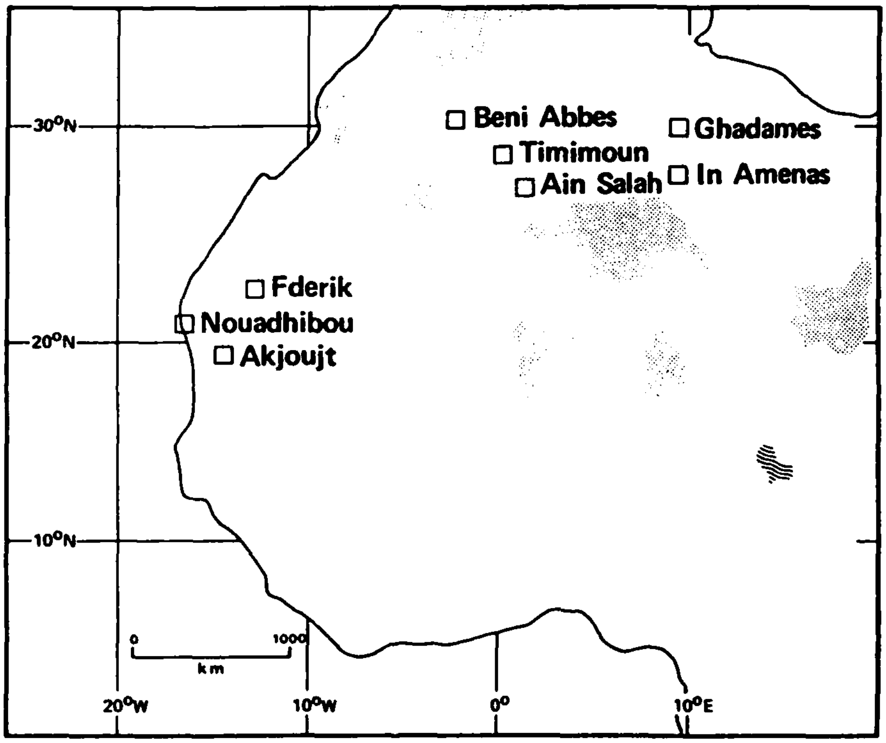
Fig. 2: Frequency of dust events versus wind speed, 1 July - 15 August, 1974: all stations combined. The frequency is expressed as a percentage of the total number of meteorological reports surveyed. Symbols: ⊞ Rising dust; + Dust in air; ◇ Haze; Δ Total.

Fig. 3: Map of West Africa. Stippled areas are important highlands.

Fig. 4: Outlines of the nine major dust storms that occurred in July 1974 in the study region as determined from SMS-1 imagery.

Fig. 5: Top, the daily surface pressures at 30^{o}N, 0^{o} and at 20^{o}N 0^{o}. Bottom, the pressure difference between these points (left hand scale) and the east-west component of the geostrophic wind (right hand scale). Days on which dust events occurred are marked with a dashed line.

Fig. 6: Ordinate, the position of the cyclone center relative to the longitude of the major dust source region. Abscissa, the pressure difference between the cyclone and the region 10^{o} to the north. Each point corresponds to a day in the study period. An "X" indicates a day on which a major dust event occurred.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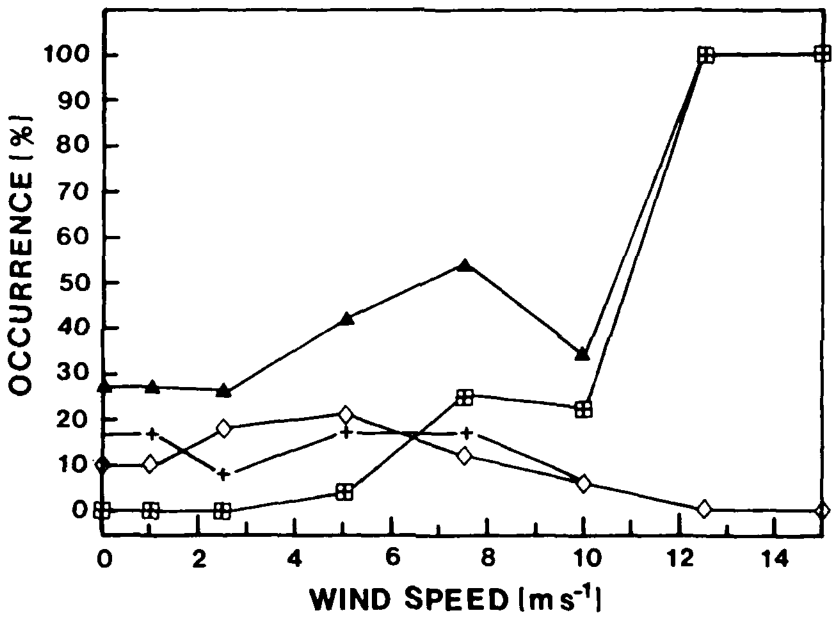
Akjoujt

Figure 1



100
90
80
70
60
50
40
30
20
10
0
OCCURRENCE [%]
0
2
4
6
8
10
12
14
WIND SPEED [m s-1]

Figure 2

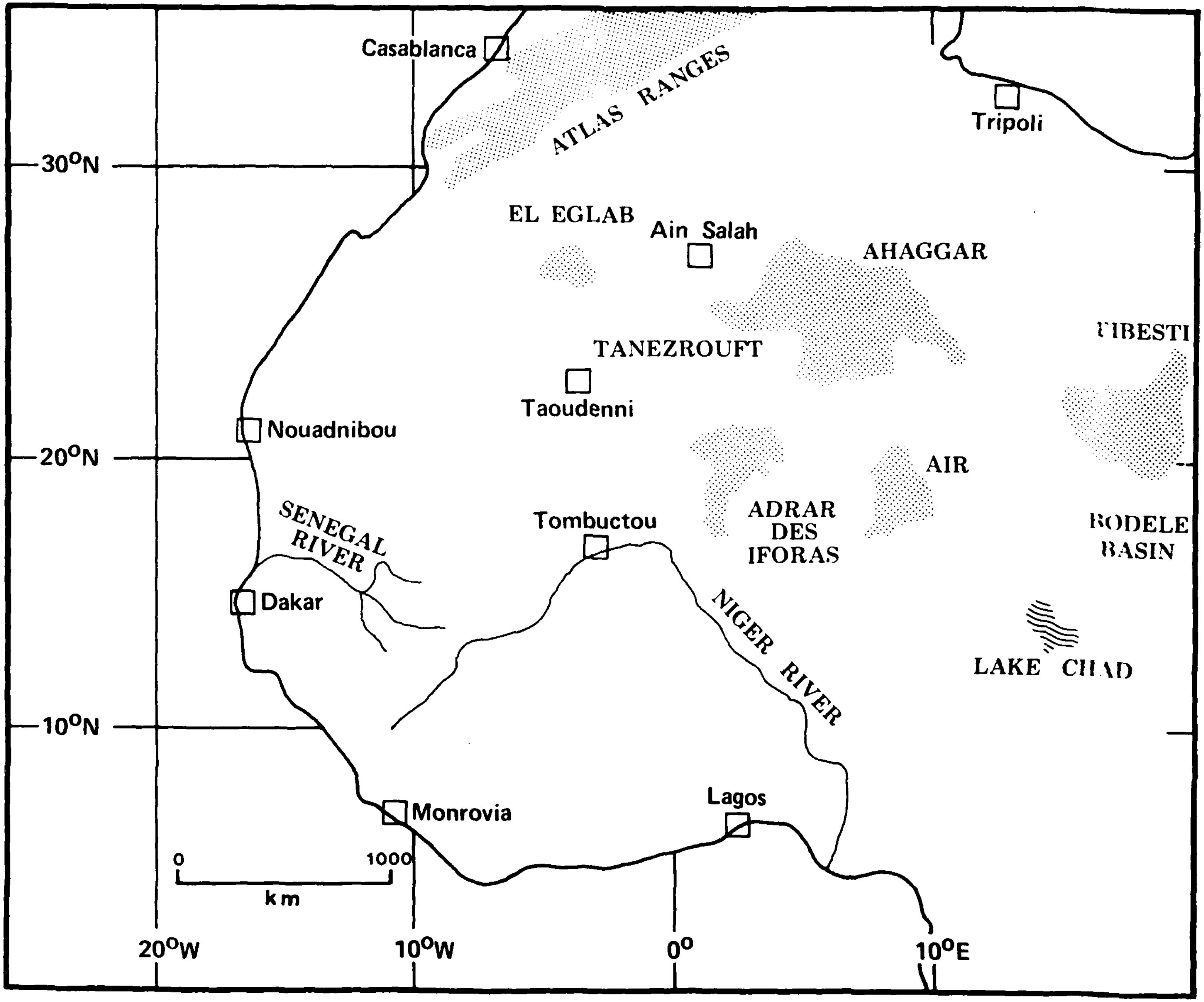

Casablanca
ATLAS RANGES
Tripoli
30°N
EL EGLAB
Ain Salah
AHAGGAR
TANEZROUFT
Taoudenni
Nouadnibou
20°N
AIR
SENEGAL RIVER
Tombuctou
ADRAR DES IFORAS
Dakar
NIGER RIVER
LAKE CHAD
10°N
Monrovia
Lagos
0
1000
km
20°W
10°W
0°
10°E

Figure 3

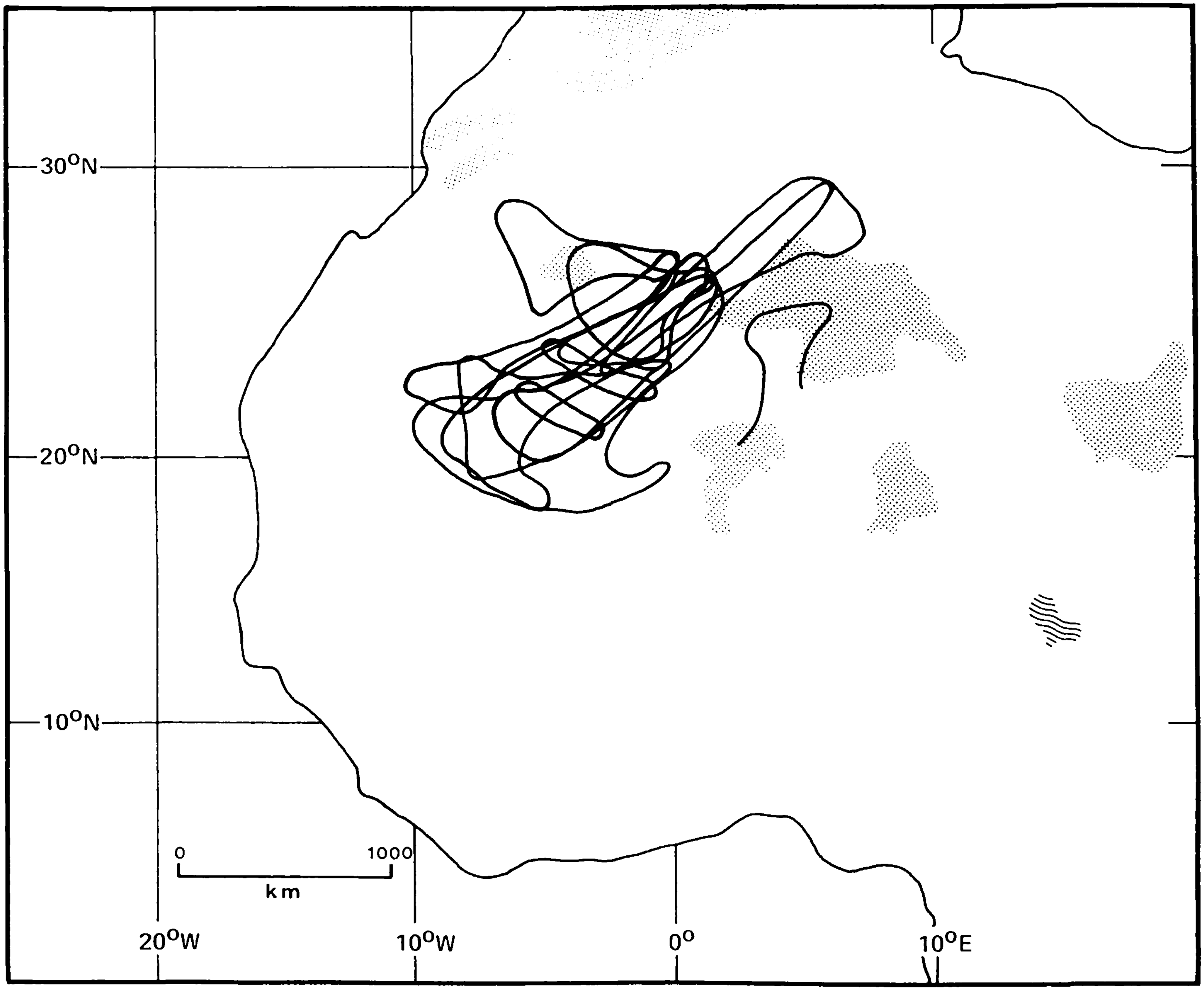


Figure 4

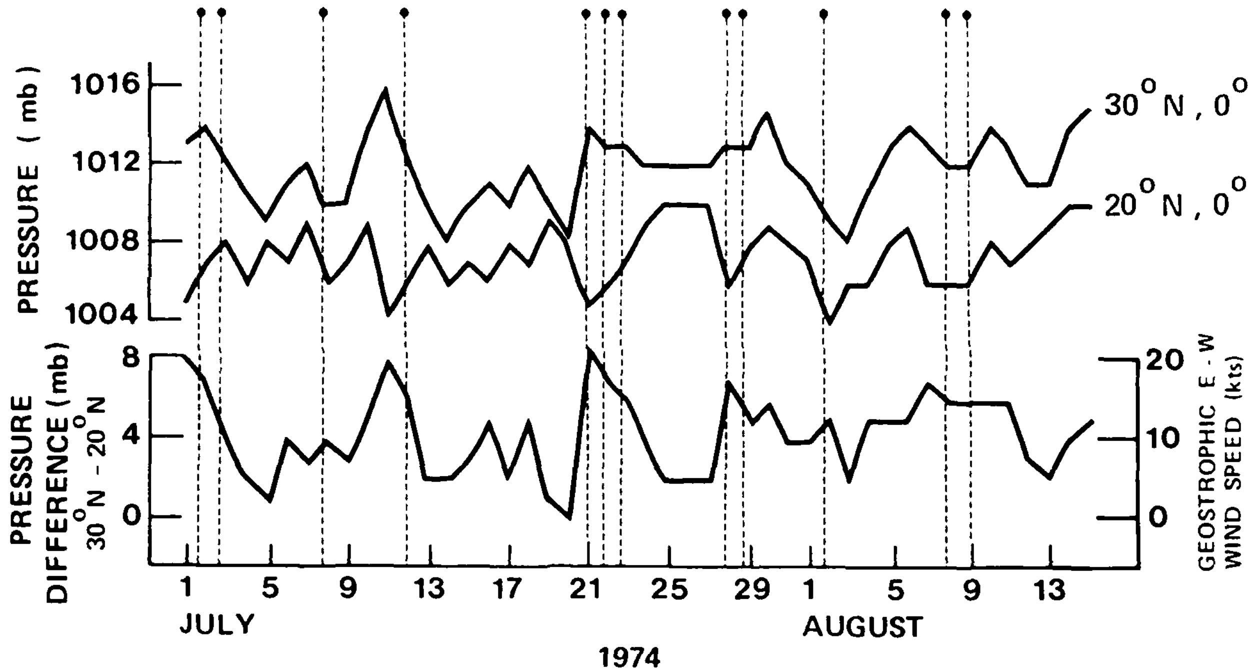

PRESSURE (mb)
1016
1012
1008
1004
30°N , 0°
20°N , 0°
PRESSURE DIFFERENCE (mb) 30°N - 20°N
8
4
0
GEOSTROPHIC E-W WIND SPEED (kts)
20
10
0
1
5
9
13
17
21
25
29
1
5
9
13
JULY
AUGUST
1974

Figure 5

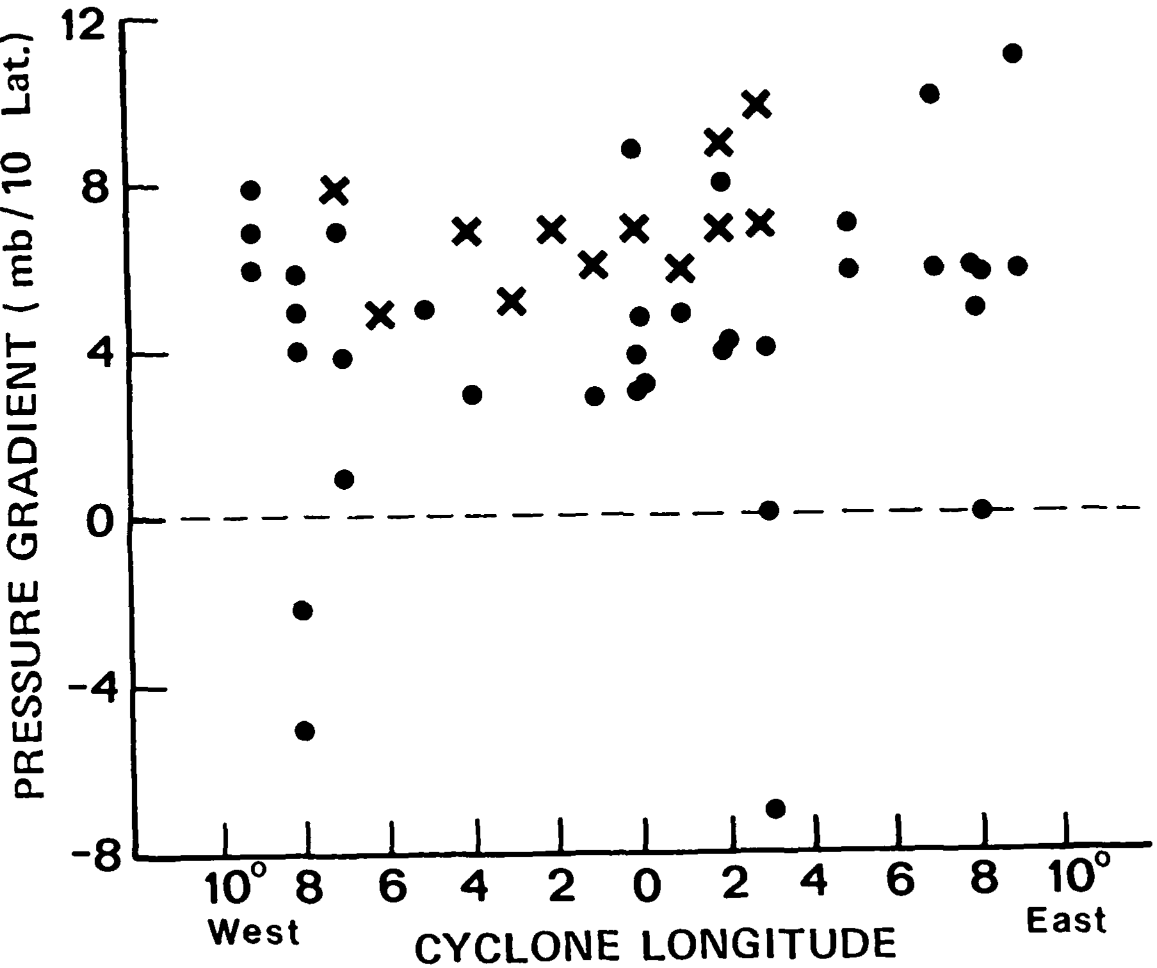

12
8
4
0
-4
-8
PRESSURE GRADIENT (mb / 10° Lat.)
10° 8 6 4 2 0 2 4 6 8 10°
West
East
CYCLONE LONGITUDE

Figure 6

List of Publications and Technical:

Helgren, D.M. and J.M. Prospero, 1984. Source terrains of the great Saharan dust storms of July 28 and 29, 1974. Presented at a meeting of the Association of American Geographers, Washington, D.C., April 21-25.

Fernandez-Partagas, J., D.M. Helgren and J.M Prospero, 1986. Threshold wind velocities for raising dust in the western Sahara. J. Clim. Appl. Meteorol. (Submitted)

Fernandez-Partagas, J., D.M. Helgren and J.M Prospero, 1986. Threshold wind velocities for raising dust in the western Sahara. Technical Report to U.S. Army Research Office, Contract No. DAAG29-83-K-0082.

Estoque, M., J. Fernandez-Partagas, D.M. Helgren and J.M. Prospero, 1986. Genesis of major dust storms in West Africa during the summer of 1974. Technical Report to U.S. Army Research Office, Contract No. DAAG29-83-K-0082.

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DTIC
END
4-86